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10/08/02

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE	
In Re Application of: M. Khare <i>et al</i>	October 8, 2002
	Examiner: Fernando L. Toledo
Serial No. 09/809,663 Filing Date: March 15, 2001	Group Art Unit: 2823
Title: METHOD FOR IMPROVED PLASMA NITRIDATION OF ULTRA THIN GATE DIELECTRICS	IBM Corporation 2070 Route 52 Dept. 18G, Bldg. 300-482 Hopewell Junction, N.Y. 12533

The Commissioner for Patents
Washington, D.C. 20231

DECLARATION UNDER 37 C.F.R. § 1.132

I, Mukesh Khare, declare as follows:

(1) I am one of the inventors of the subject matter disclosed and claimed in the patent application identified above.

(2) I received a Ph.D. from Yale University in 1999. The subject of my dissertation is "Advanced Gate Dielectric for ULSI Applications." I have also received the following degrees: a Master of Philosophy in Electrical Engineering (Microelectronics) from Yale University; a Master of Science in Electrical Engineering (Microelectronics) from Yale University; a Master of Technology in Electrical Engineering (Microelectronics) from the Indian Institute of Technology

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in Bombay, India; and a Bachelor of Engineering in Electronics Engineering from Bombay University.

(3) I have been employed by IBM Microelectronics Division since 1998 in the Semiconductor Research and Development Center as lead integration engineer for 90 nm high performance technology. Before working at IBM, I worked at Motorola as an engineering intern in 1997 evaluating advanced processes for gate dielectric application in ultra-thin regime, and in 1996 characterizing capacitors and field effect transistors made with jet vapor deposition (JVD) nitride as gate dielectric. I also worked at Yale University Center for Microelectronic Materials and Structures on developing and investigating the properties of ultra-thin silicon nitride gate dielectric using JVD as a replacement of silicon dioxide for deep-sub-micron devices.

(4) I have published numerous technical articles relating to semiconductor applications, including: (1) Terence B. Hook, Anthony Chou, Mukesh Khare, Anda Mocuta, "A Circuit Model for Evaluating Plasma-Induced Charging Damage in Bulk and SOI Technologies," International Symposium on Plasma Process-Induced Damage, P2ID, Proceedings 2000. p 30-33; (2) Anda C. Mocuta, Terence B. Hook, Anthony I. Chou, Tina Wagner, Anthony K. Stamper, Mukesh Khare, Jeffrey P. Gambino, "Plasma charging damage in SOI Technology," 6th International Symposium on Plasma- and Process-Induced Damage, International Symposium on Plasma Process-Induced Damage, P2ID, Proceedings 2001 p.104-107; and (3) H. Park, D. Schepis, A.C. Mocuta, Mukesh Khare, Y. Li, B. Doris, S. Shukla, T. Hughes, O. Dokumaci, S. Narasimha, S. Fung, J. Snare, B.H. Lee, J. Li, P. Ronsheim, *et al.*, "Gate postdoping to decouple implant/anneal for gate, source/drain, and extension: Maximizing polysilicon gate activation for 0.1 mum CMOS technologies," 2002 Symposium on VLSI Technology Digest of Technical Papers, IEEE Symposium on VLSI Circuits, Digest of Technical Papers 2002 p.134-135.

(5) From my experience in the field of semiconductor fabrication, I am very knowledgeable about gate dielectric formation using plasma nitridation.

(6) I am familiar with the above-referenced patent application ("present application"), and its prosecution at the U.S. Patent and Trademark Office.

(7) The above-referenced patent application is directed to a method for forming a gate dielectric for an integrated circuit device. The method includes the following steps: (a) forming an initial oxynitride layer upon a substrate material, the initial oxynitride layer having an initial physical thickness; and (b) subjecting the initial oxynitride layer to a plasma nitridation, the plasma nitridation resulting in a final oxynitride layer having a final physical thickness. The final oxynitride layer has an equivalent oxide thickness (EOT) of less than 15 angstroms and a nitrogen concentration of at least 2.0×10^{15} atoms/cm².

(8) Claims 1-3 and 6-8 have been rejected as anticipated by or obvious over U.S. Patent No. 6,136,654 to Kraft *et al.*, either alone or in combination with other references. The basis for these rejections, as stated in the Office Action mailed August 8, 2002, is that Figure 7 of the Kraft *et al.* patent discloses a final oxynitride layer having an EOT of less than 15 angstroms and a nitrogen concentration of at least 2.0×10^{15} atoms/cm². A further basis for these rejections, as stated in the Interview Summary mailed September 19, 2002, is that Figure 8 discloses an EOT of less than 15 angstroms, that the processes used to produce the Figure 7 and Figure 8 films are similar, and therefore the nitrogen concentration must also be similar.

(9) In my opinion, a person of skill in the art to which the present application is directed would understand that the Figure 7 film in the Kraft *et al.* patent does not have an EOT of less than 15 angstroms. Figure 7 of the Kraft *et al.* patent is a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft *et al.* invention. The patent discloses that Figure 7 illustrates data taken from a SIMS analysis of "a 35 oxide film" nitrided under specified conditions (col. 5, lines 45-48). In my opinion, the phrase "a 35 oxide film" was intended to mean "a 35 angstrom oxide film" for the following reasons. First, Figure 7 illustrates nitrogen and oxygen concentration as a function of depth in the gate dielectric film, and the units of measure on the x-axis of this graph are "angstroms." Moreover, in the discussion of

Figure 7, it is stated that Figure 7 shows a substantially complete formation of silicon nitride (col. 5, lines 52-54). It is well known that a relatively strong concentration of nitrogen ($2.0 \times 10^{15}/\text{cm}^2$ or greater) introduced into an oxide layer by plasma nitridation causes additional growth of the layer. Thus, if a 35 angstrom oxide film were nitrided under the conditions disclosed in the Kraft *et al.* patent, such that substantially complete formation of silicon nitride results, one skilled in the art would expect the final thickness of the nitrided film to be greater than 35 angstroms. Furthermore, a careful look at the SIMS plot shows that the nitrogen concentration does not go down to less than 5% until a depth of more than 35 angstroms. This plot clearly shows that the physical thickness of this film after plasma nitridation is more than 35 angstroms. Since Figure 7 shows that the nitrogen concentration in the nitrided film was measured to a depth of over 50 angstroms, the initial oxide film thickness was most likely 35 angstroms. This film with final thickness greater than 35 angstroms, even with high level of nitridation, can not have an EOT of less than 15 angstroms.

(10) It is also my opinion that a person skilled in the art would understand that the Figure 8 film in the Kraft *et al.* patent does not have an EOT of less than 15 angstroms. Figure 8 is also a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft *et al.* invention. The patent discloses that Figure 8 illustrates data taken from a time of flight SIMS analysis of "a 7 oxide film" nitrided under specified conditions (col. 5, lines 54-56). In my opinion, the phrase "a 7 oxide film" was intended to mean "a 70 angstrom oxide film" for the following reasons. First, the units of measure for the initial thickness of the oxide film must be angstroms for the same reasons discussed above with respect to Figure 7. The units of measure on the x-axis of the Figure 8 graph are angstroms. Second, the initial thickness of the oxide film must have been 70 angstroms rather than 7 angstroms for several reasons. Kraft *et al.* disclose that the initial oxide-containing layer is preferably "a 10 to 150 [angstrom] thick" layer (col. 3, line 52). A 70 angstrom oxide film falls within this range whereas a 7 angstrom oxide film does not. More importantly, however, Figure 8 indicates that the nitrogen and oxygen concentrations in the nitrided film were measured to a depth of 90 angstroms, and that the nitrogen concentration does not begin to drop until the film thickness is about 70 angstroms. At a

thickness of about 7 angstroms, the nitrogen signal is just beginning to rise. If the final film thickness were 7 angstroms, as the Examiner alleges, then the nitrogen concentration should be zero for depths greater than 7 angstroms. In fact, Figure 8 shows the highest nitrogen concentration at 20 to 25 angstroms, and the nitrogen signal drops to a very low value after 70 angstroms. This clearly supports a conclusion that there is an error in the text of the Kraft *et al.* patent, such that the initial oxide film thickness should be 70 angstroms rather than 7 angstroms.

(11) It is my further opinion that the process conditions used by Kraft *et al.* for the Figure 8 film would not have produced a final film having an EOT of less than 15 angstroms and a nitrogen concentration of at least 2.0×10^{15} atoms/cm² for the following reasons. First, it is important to note that the process of the present application begins with forming a heavily nitrided initial oxynitride layer, and concludes with subjecting this initial layer to a light nitridation in order to minimize growth of the layer. Kraft *et al.* fail to disclose any process conditions used to form an initial oxynitride layer. Indeed, Kraft *et al.* teach only that the initial layer should be an oxide-containing layer, preferably an oxide layer. Moreover, the nitridation process conditions disclosed by Kraft *et al.* indicate that their initial film is subjected to a heavy nitridation, causing significant growth of the film. The differences in process conditions are summarized in the Tables 1-3 below.

1. Formation of initial oxynitride layer by rapid thermal nitric oxide (RTNO) deposition

Process condition	IBM process	Kraft <i>et al.</i> process
Temperature	650 to 850 °C	not disclosed
Pressure	10 to 740 Torr	not disclosed
Duration	30 to 90 seconds	not disclosed

2. Formation of initial oxynitride layer by nitrogen ion implantation and rapid thermal oxidation

Process condition	IBM process	Kraft <i>et al.</i> process
Nitrogen ion implant dose	3×10^{14} to 8×10^{14} atoms/cm ²	not disclosed
RTO temperature	900 to 1000 °C	not disclosed
RTO time	5 to 15 seconds	not disclosed

3. Plasma nitridation of initial oxynitride layer

Process condition	IBM process (light nitridation)	Kraft <i>et al.</i> process (heavy nitridation)
Plasma power	3000 Watts	2000 Watts
Frequency	2.1 Ghz	13.56 MHz
Substrate bias	no substrate bias	450 Watts (for Fig. 8)
Nitrogen flowrate	500 to 2000 sccm	100 sccm
Helium flowrate	1000 to 5000 sccm	not disclosed
Pressure	2 to 5 Torr	4 mTorr
Duration	50-150 seconds	10 seconds (for Fig. 8)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the above-identified application or any patent issued thereon.

By: Mukesh V. Khare

Date: 10/8/2002

Mukesh V. Khare